Linear Optics

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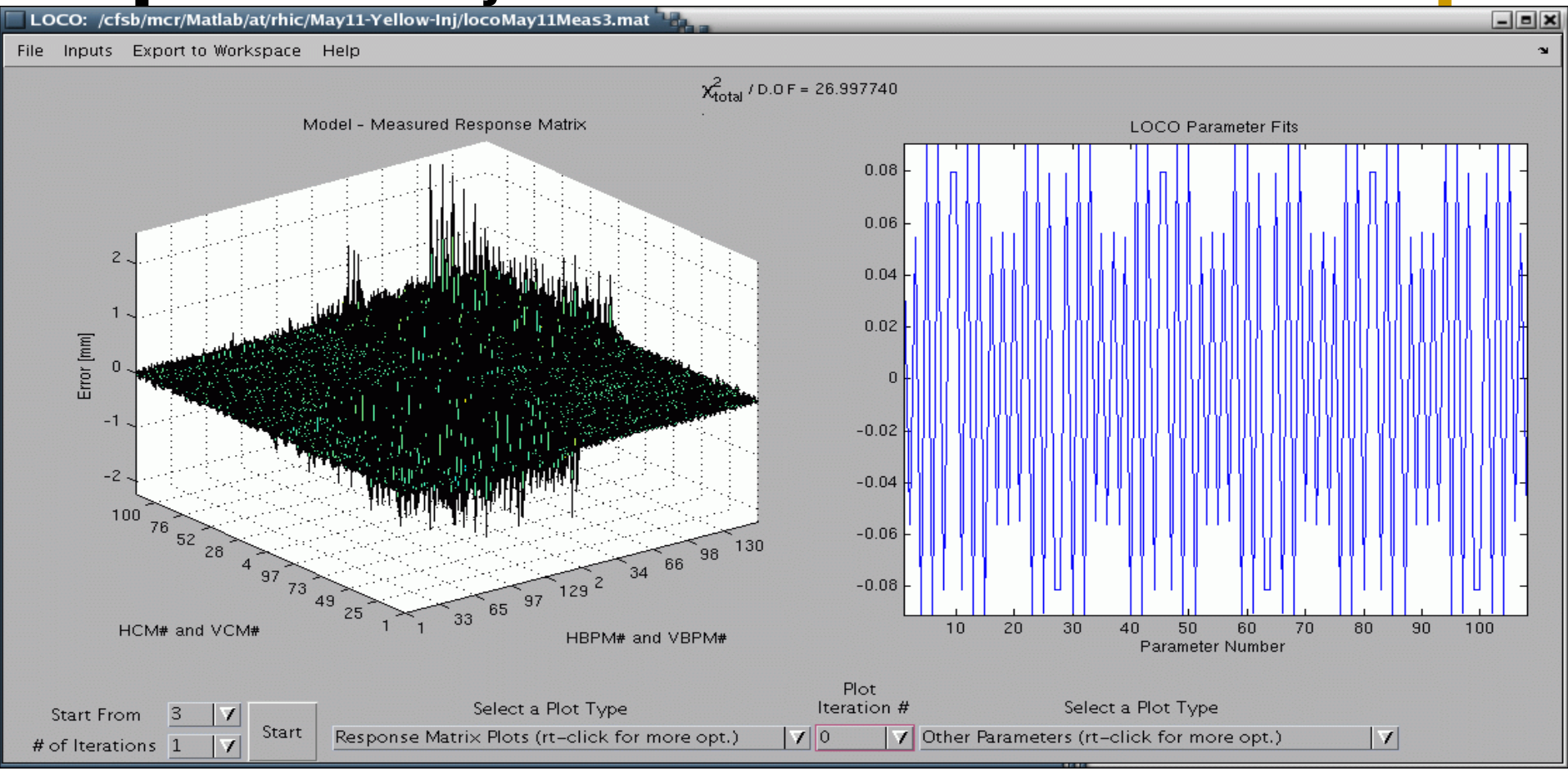
Tools we have for linear optics

- ORM: orbit response matrix
  - Imported loco package before the run
  - Deliverables
    - Beta functions: offline
    - Bpm errors: offline
    - Gradient errors: offline
- ac dipole
  - Deliverable:
    - Beta functions including beta *: online
    - Phase advances: online
    - Gradient errors: offline: could be online

Datasets we collected during FY06

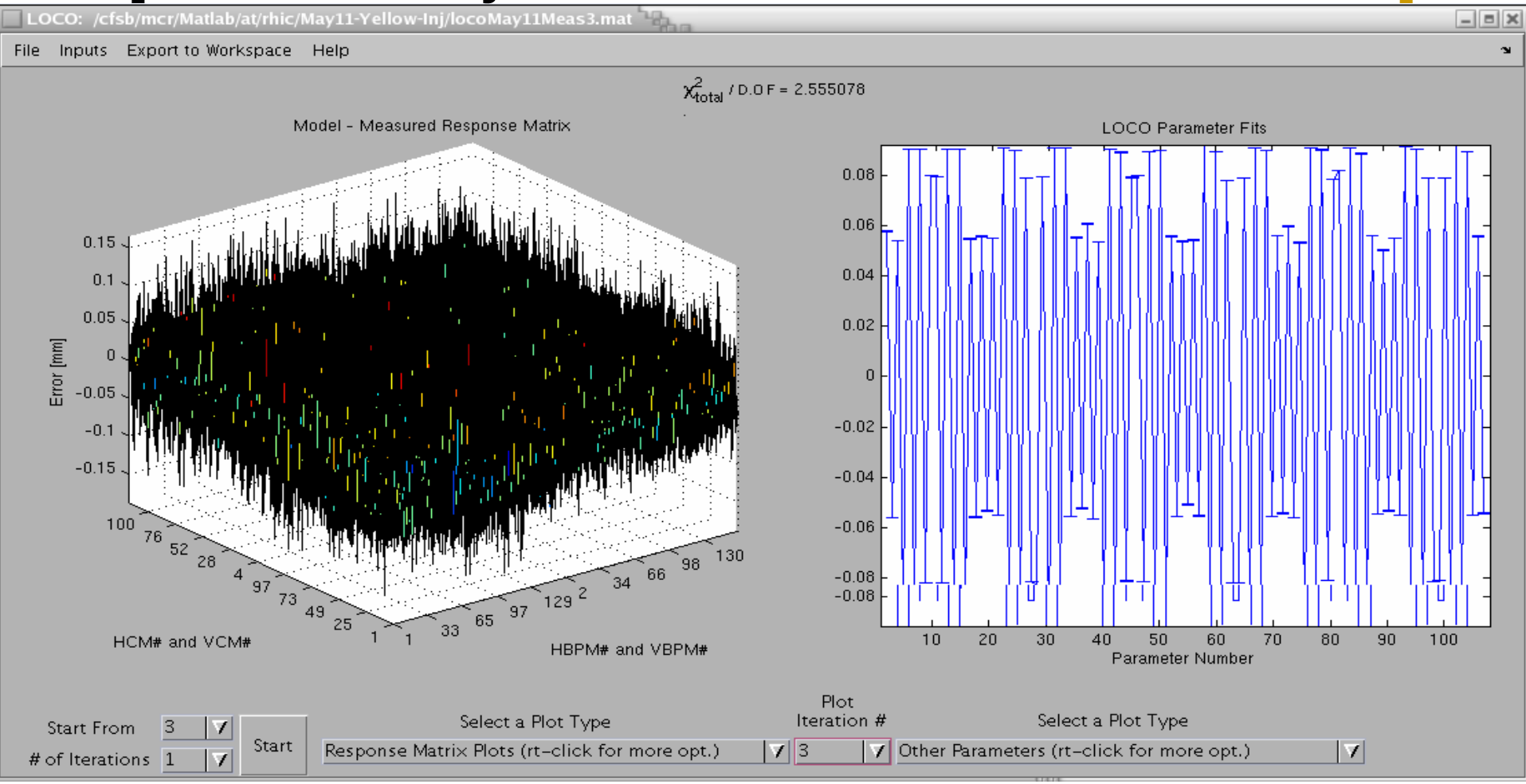
- ORM: orbit response matrix
  - Yellow: injection and store (100 GeV)
- ac dipole
  - Injection: Blue and Yellow, one fill
  - Store: Blue and Yellow, one fill

Yellow injection ORM



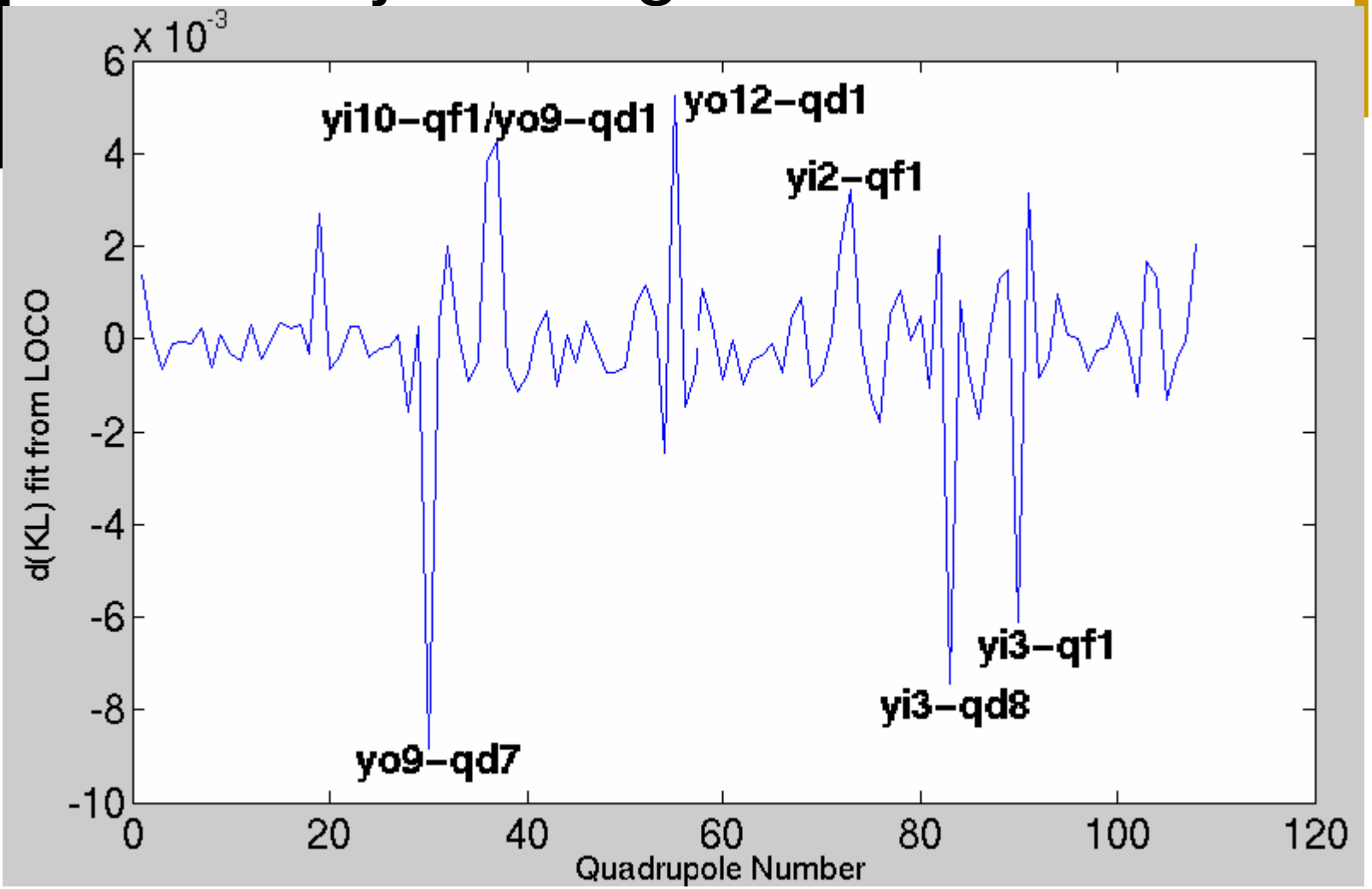
- the original difference between the model and measured orbit response matrices, and the initial parameters(fit IR Q9-Q9), ignoring arc quads.
- Fit with all quadrupoles, including arc quads, and it converged to the same solution

Yellow injection ORM -- fitted



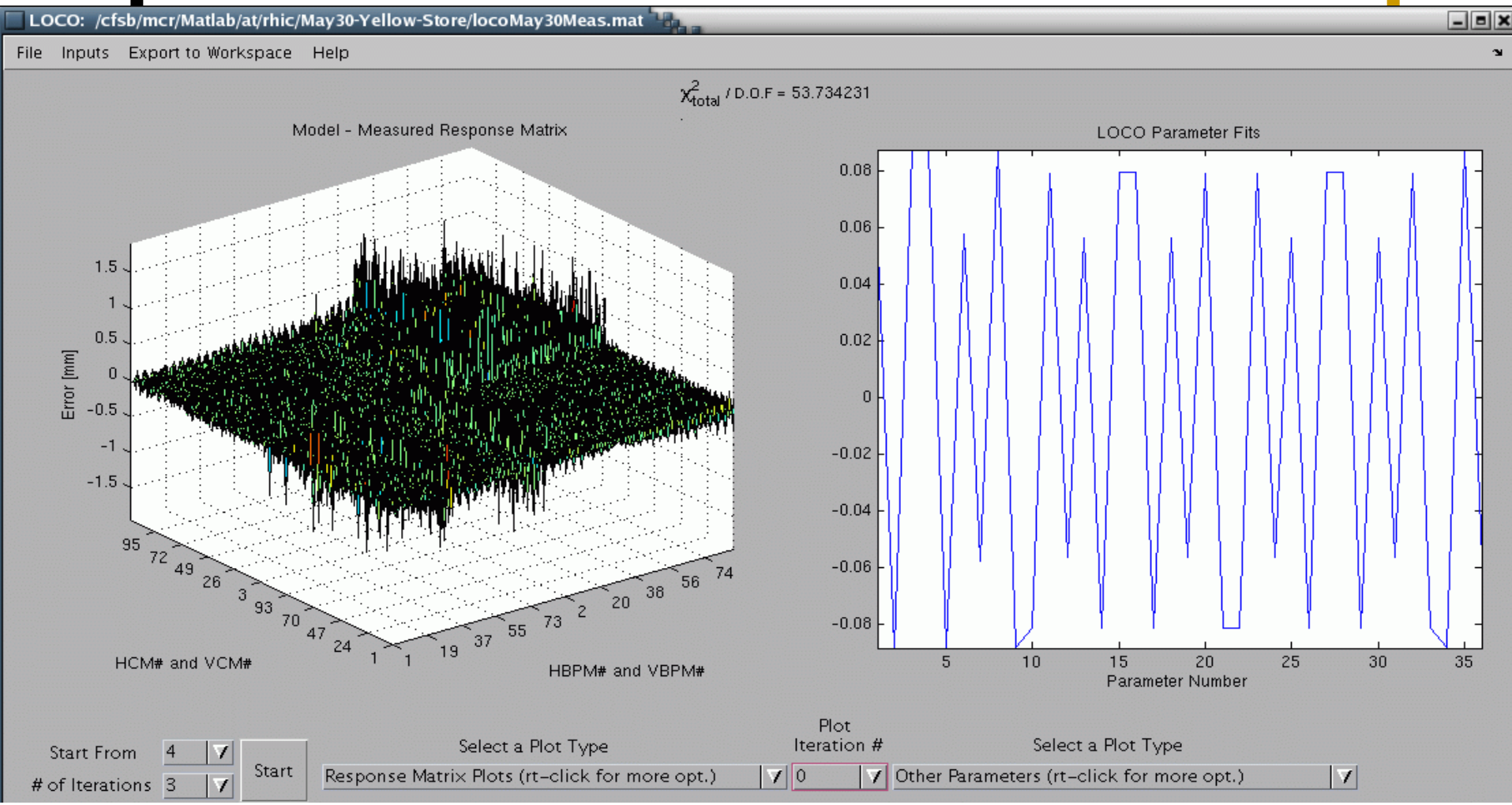
- the fit after 3 iterations of LOCO. The difference orbit response is getting close to the BPM noise of about 100 um or so, and the chi^2 has come down a lot. Even though, this fit was done WITHOUT using dipole corrector errors, BPM errors, or coupling, this gives reasonable (and consistent) gradient errors.
- Fitting with dipole and bpm errors may reduce the chi^2 even more

Yellow injection gradient error



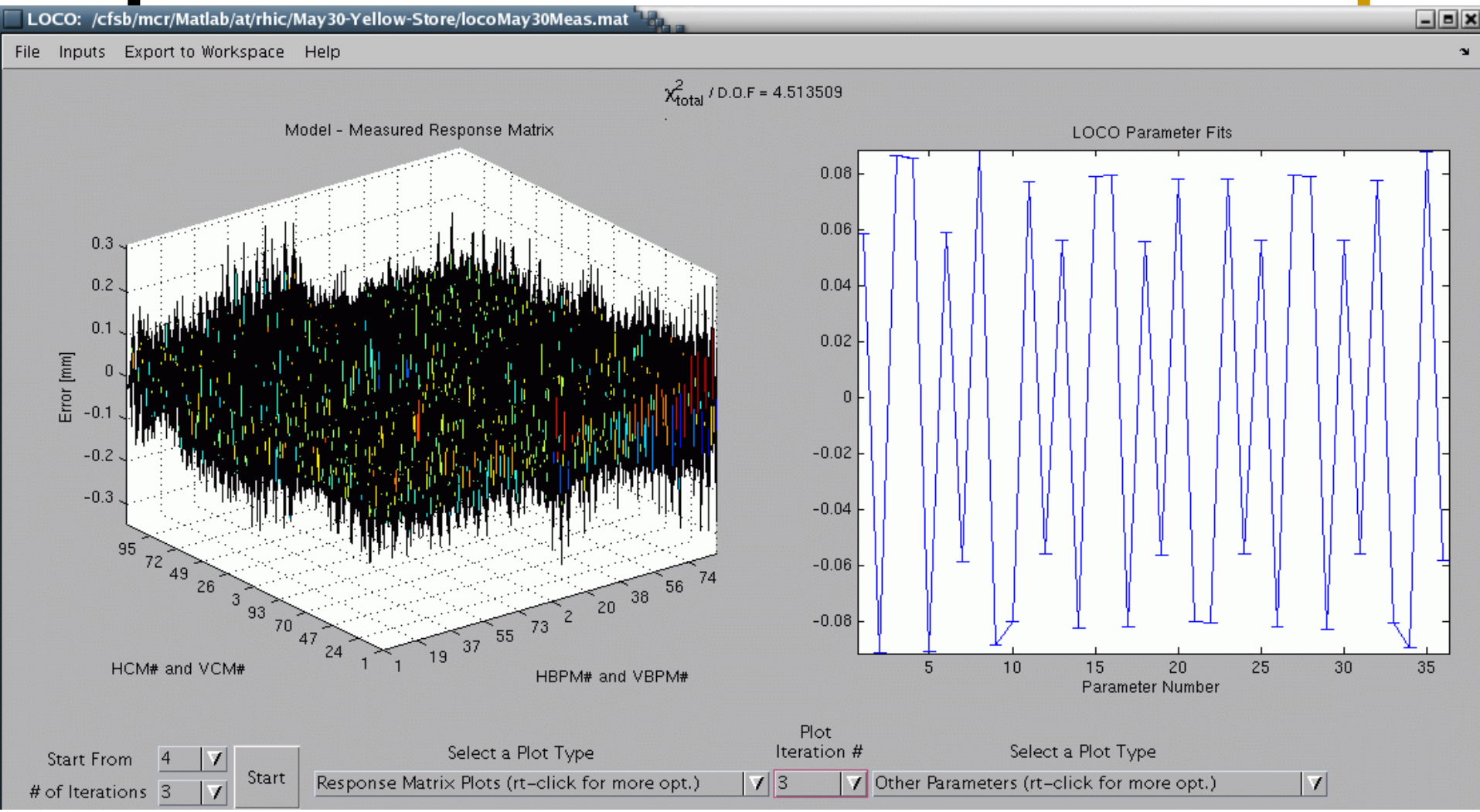
- the gradient errors as a function of quad index in the fitting. They are at most 10 percent of the quadrupole strengths themselves
- the average of d(KL) is about zero -- the ORM fit is not trying to compensation for a tune difference between measurement and model.

Yellow store ORM



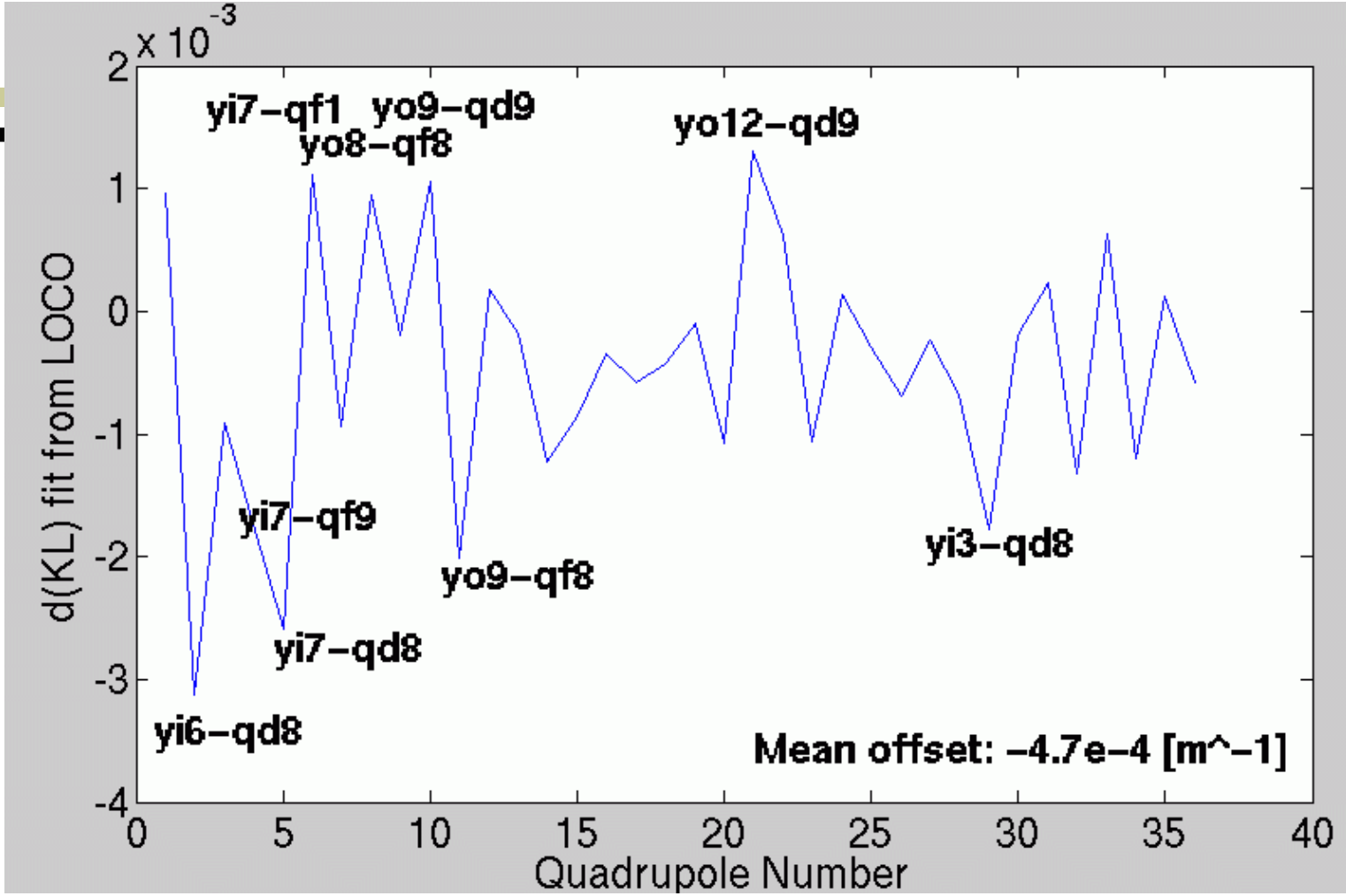
- Difference of measured ORM vs. model ORM. However, can only fit with Q1/8/9. Other attempts like using all the Q9-Q9 or all the quads failed to converge. Reasons under investigation

Yellow store fitted ORM

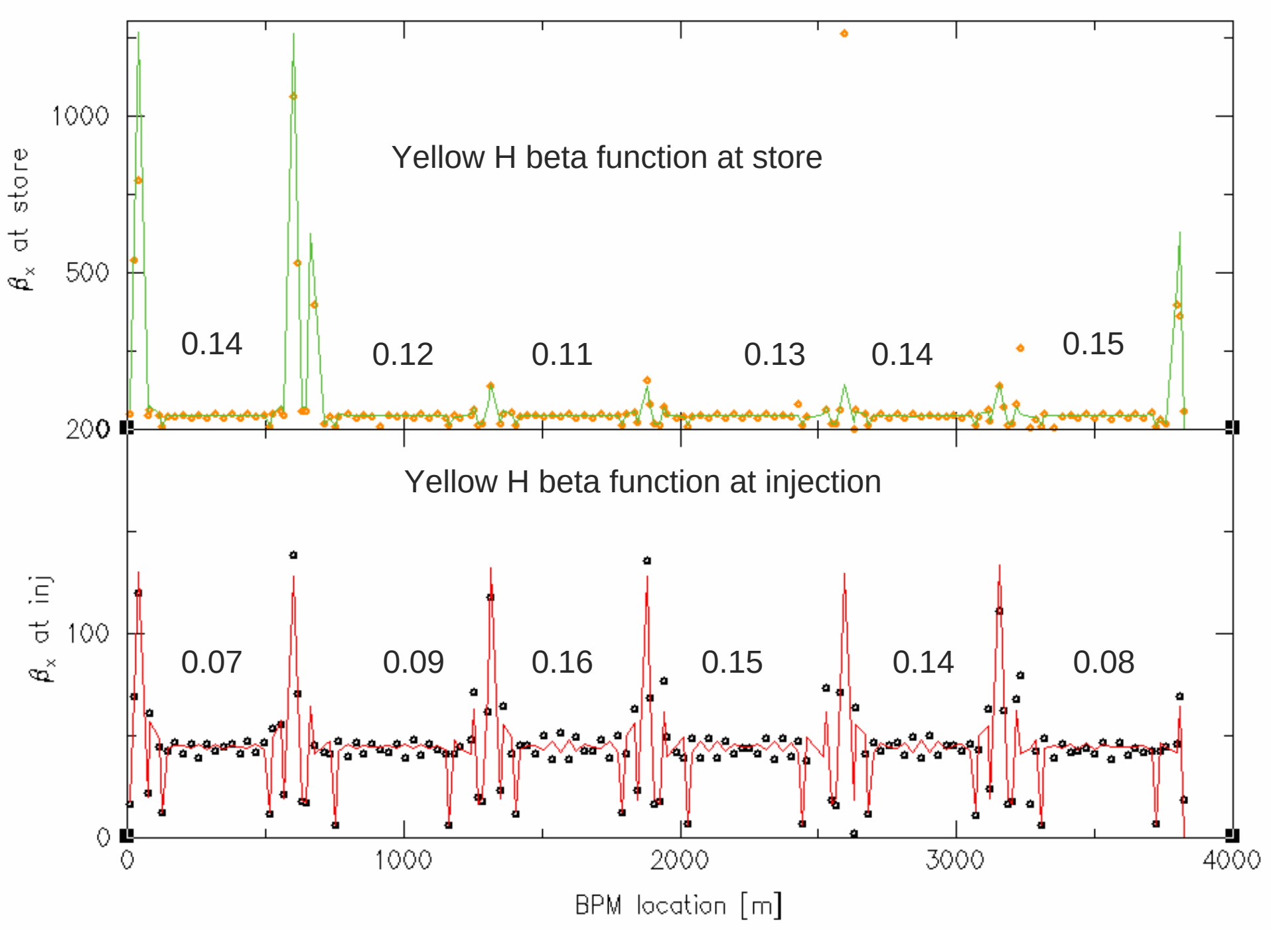


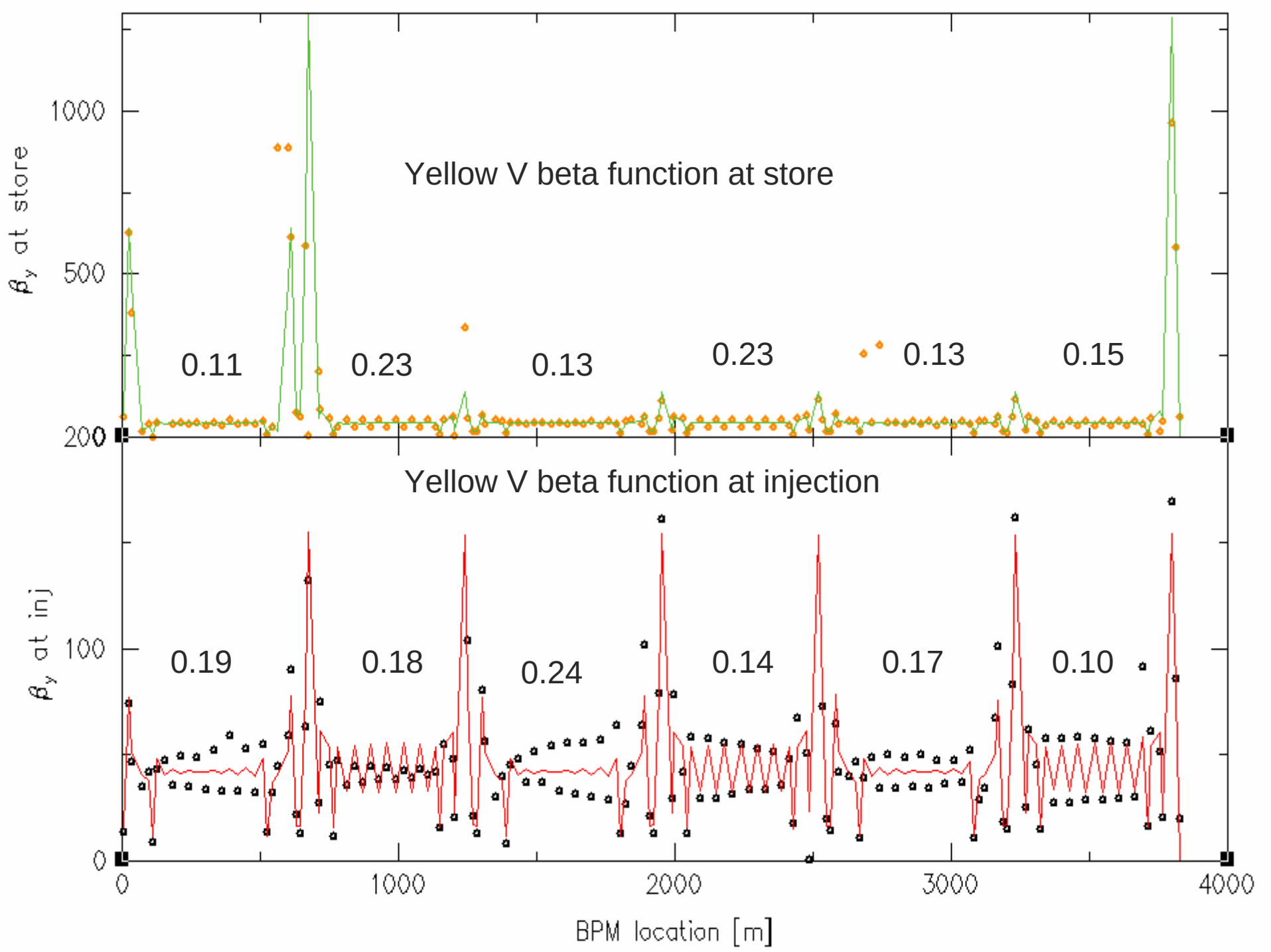
- Difference of measured ORM vs. fitted model ORM

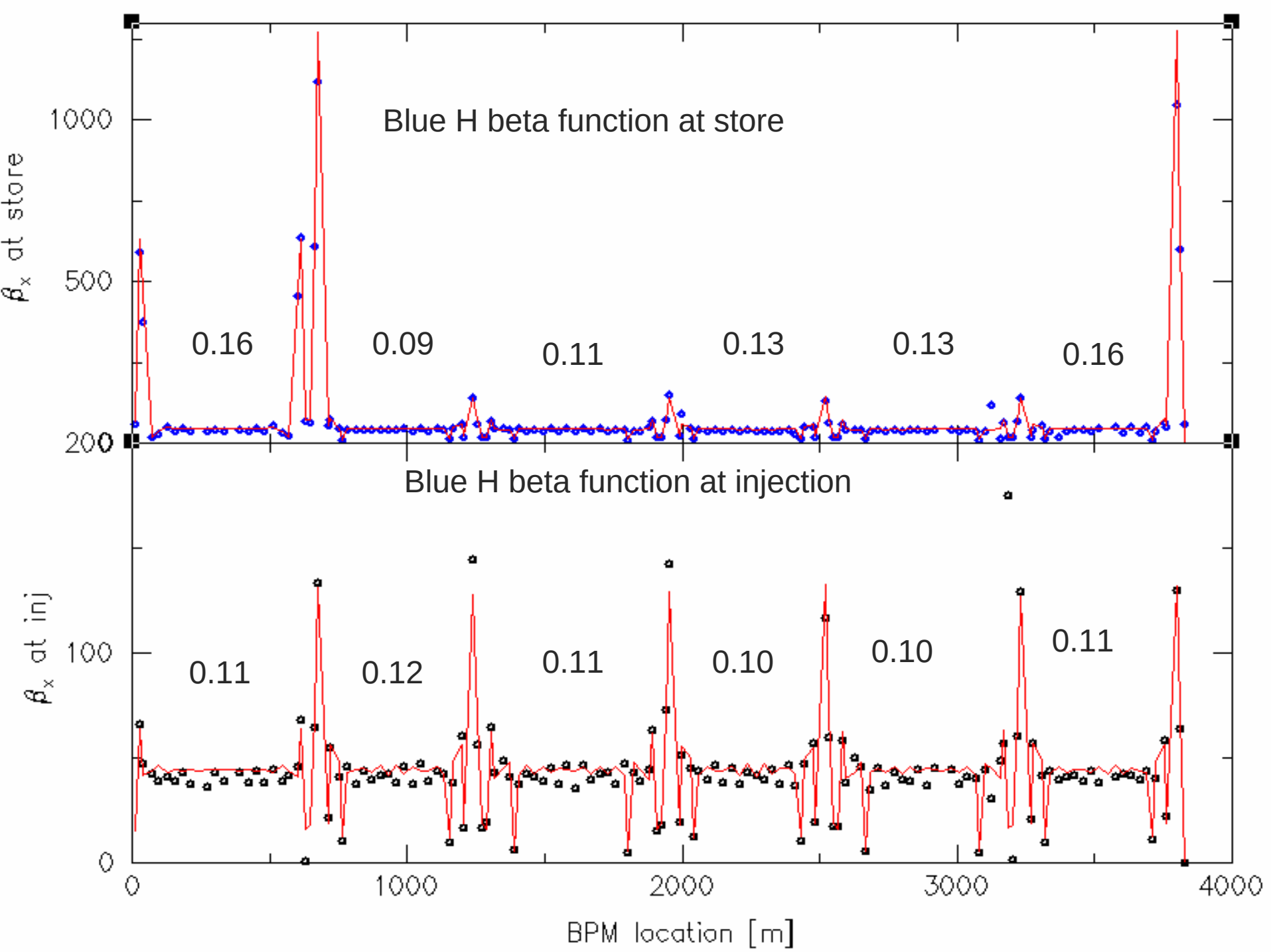
Yellow store gradient error

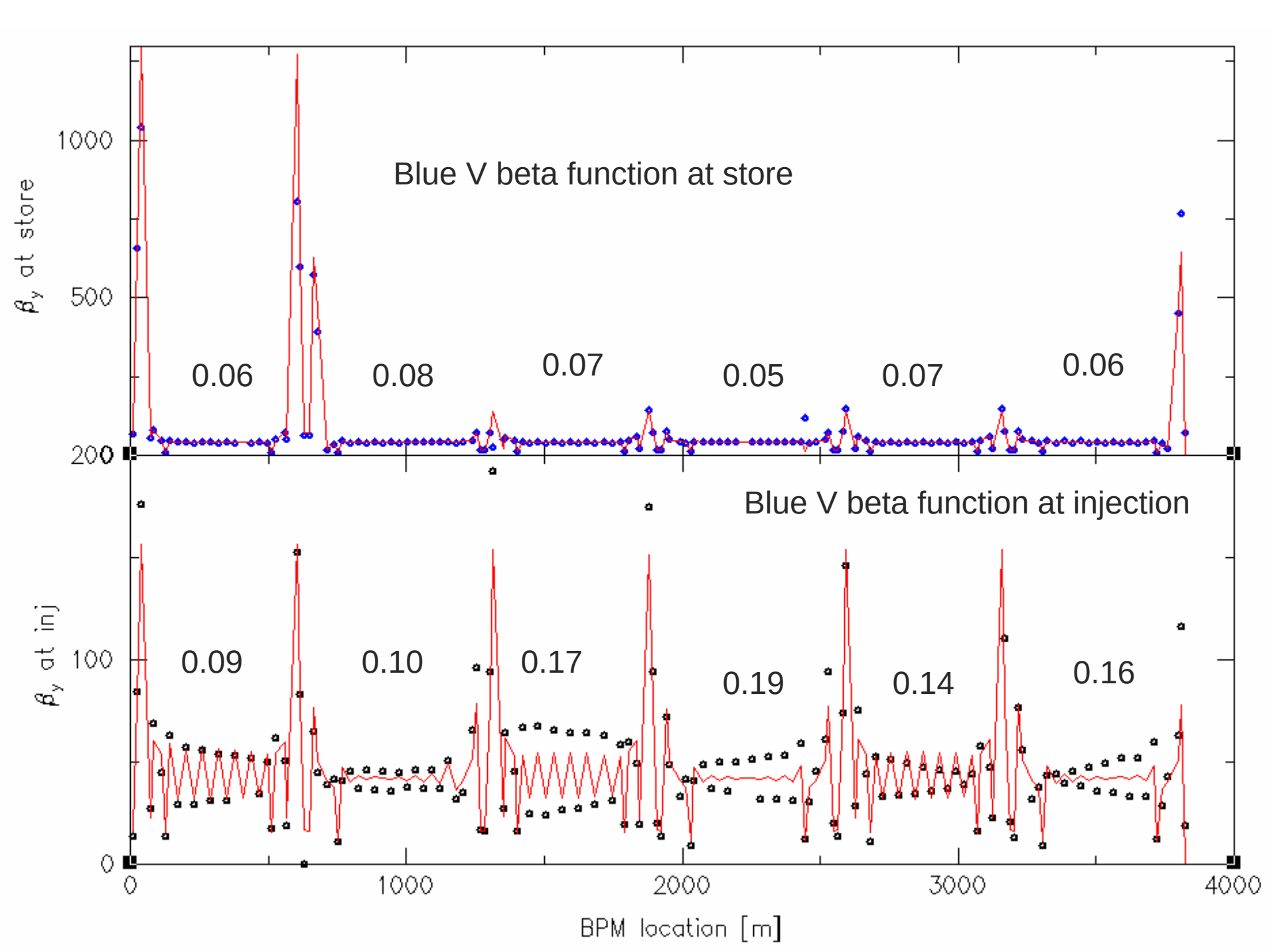


- the gradient errors as a function of quad index in the fitting.


Yellow H beta function at store
β_x at store
1000
500
200
0.14
0.12
0.11
0.13
0.14
0.15
Yellow H beta function at injection
β_x at inj
100
0
0.07
0.09
0.16
0.15
0.14
0.08
0
1000
2000
3000
4000
BPM location [m]


Yellow V beta function at store
β_y at store
1000
500
200
0.11
0.23
0.13
0.23
0.13
0.15
Yellow V beta function at injection
β_y at inj
100
0
0.19
0.18
0.24
0.14
0.17
0.10
0
1000
2000
3000
4000
BPM location [m]


Blue H beta function at store
β_x at store
1000
500
200
0.16
0.09
0.11
0.13
0.13
0.16
Blue H beta function at injection
β_x at inj
100
0
0.11
0.12
0.11
0.10
0.10
0.11
0
1000
2000
3000
4000
BPM location [m]


Blue V beta function at store
β_y at store
1000
500
200
0.06
0.08
0.07
0.05
0.07
0.06
Blue V beta function at injection
β_y at inj
100
0
0.09
0.10
0.17
0.19
0.14
0.16
0
1000
2000
3000
4000
BPM location [m]

Betawave response matrix

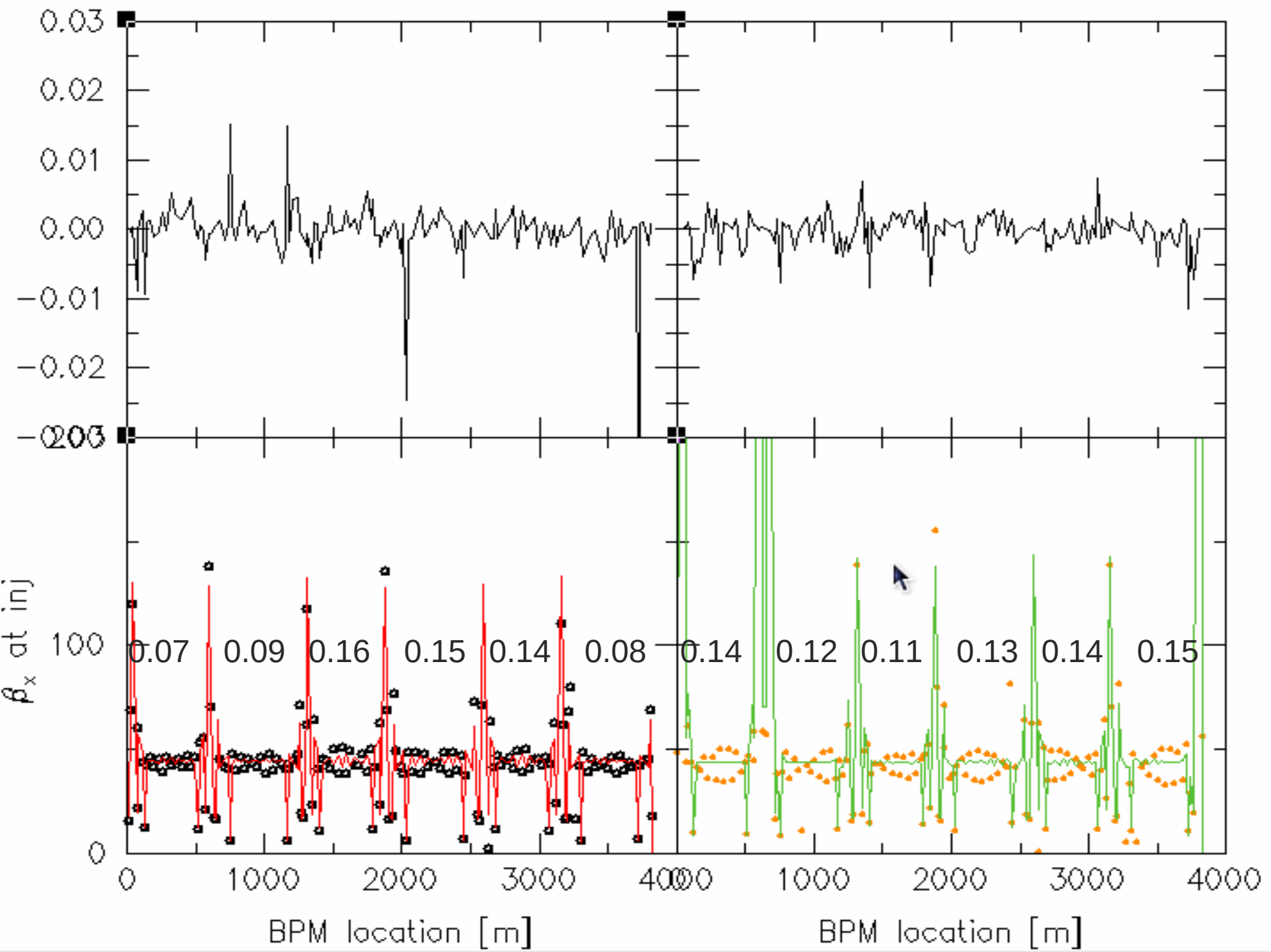
$$\frac{\Delta\beta}{\beta} = -\frac{1}{2\sin(2\pi Q)} \sum_{i}^{nquad} \Delta k_i \beta_i \cos(2\pi Q + 2(\psi - \psi_i))$$

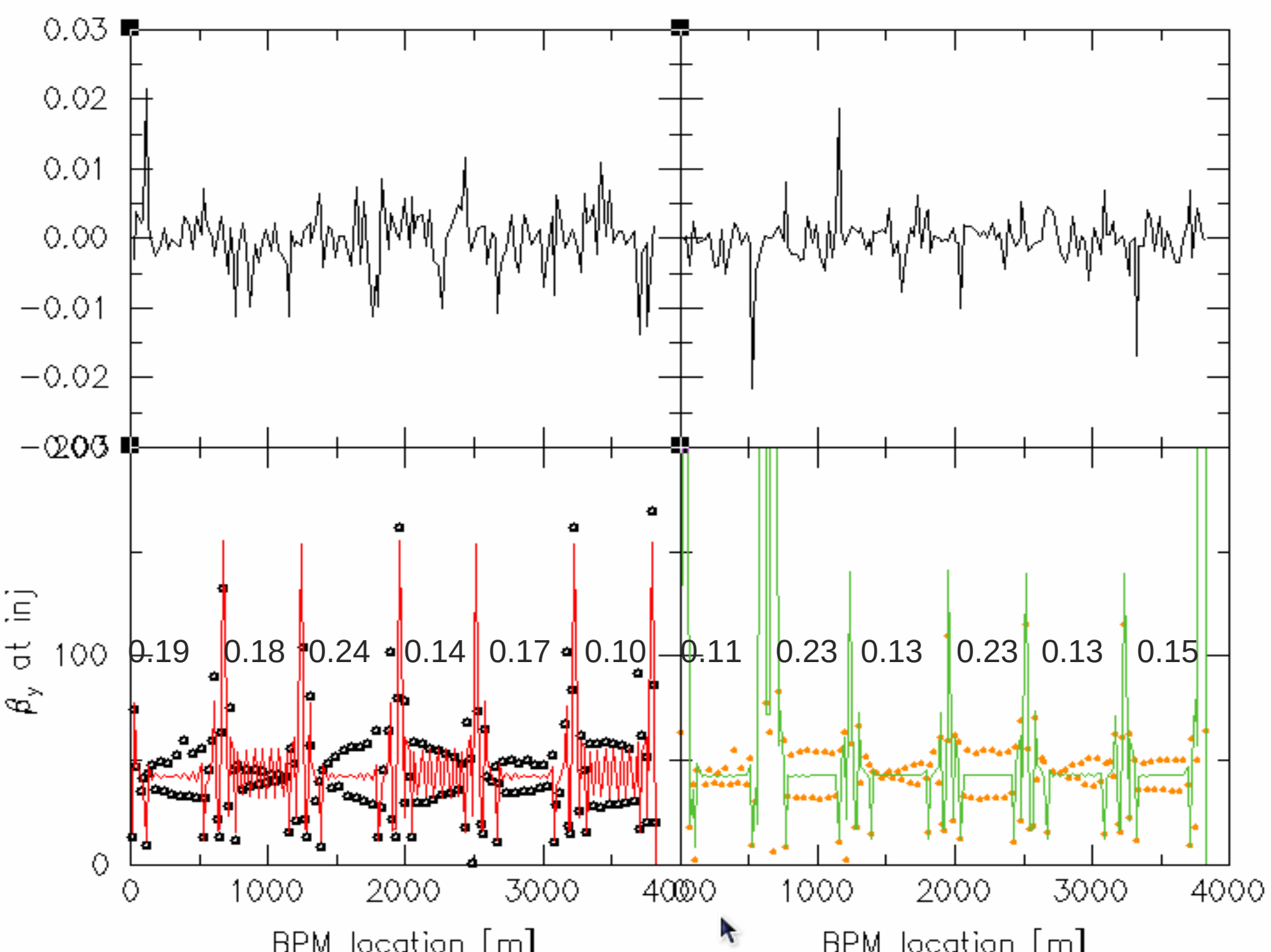
Phase advance

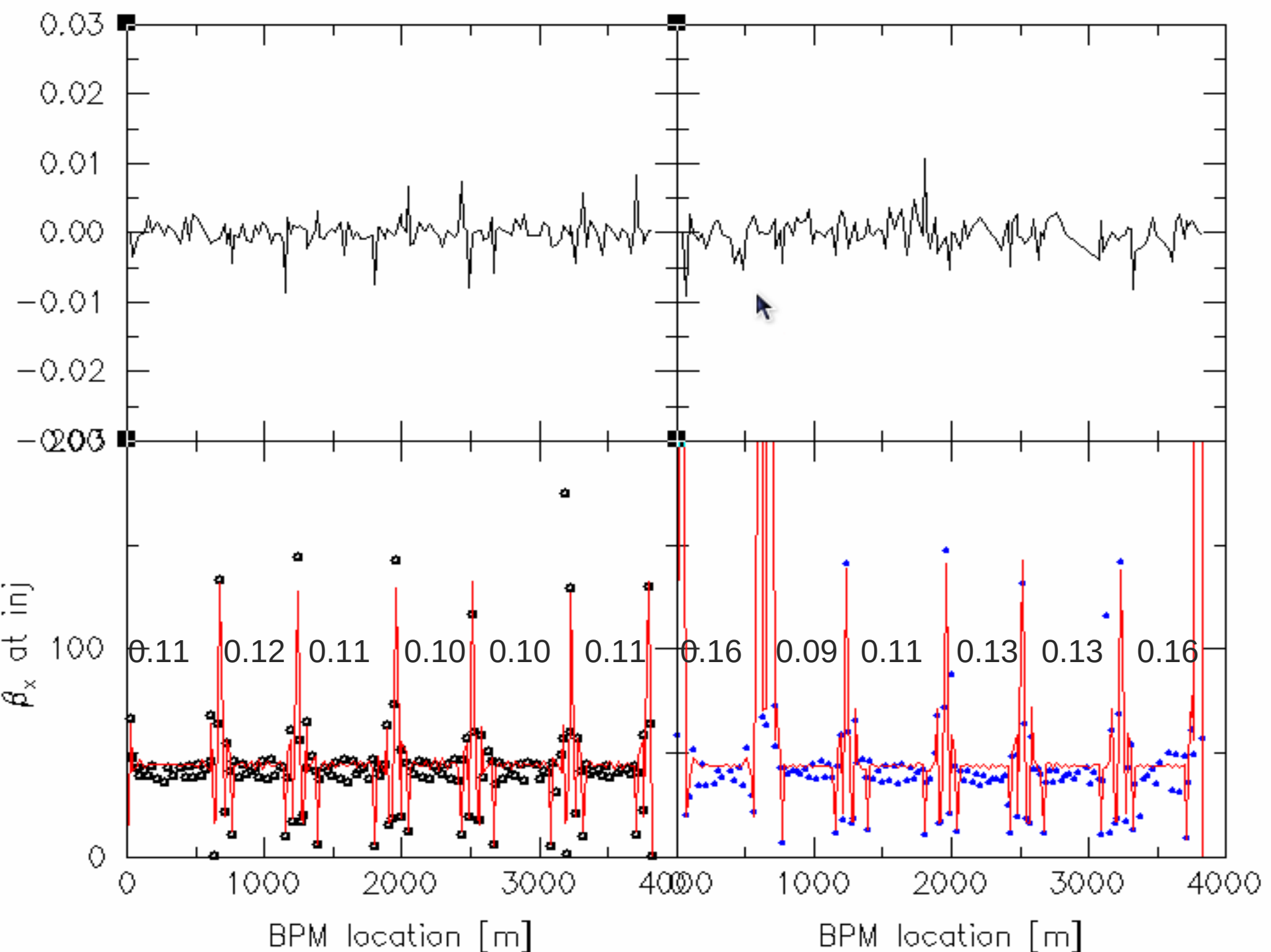
$$\left(\frac{\Delta\beta_j}{\beta_j}\right)_{nbpm} = (M)_{nbpmxnquad} (\Delta k_i)_{nquad}$$

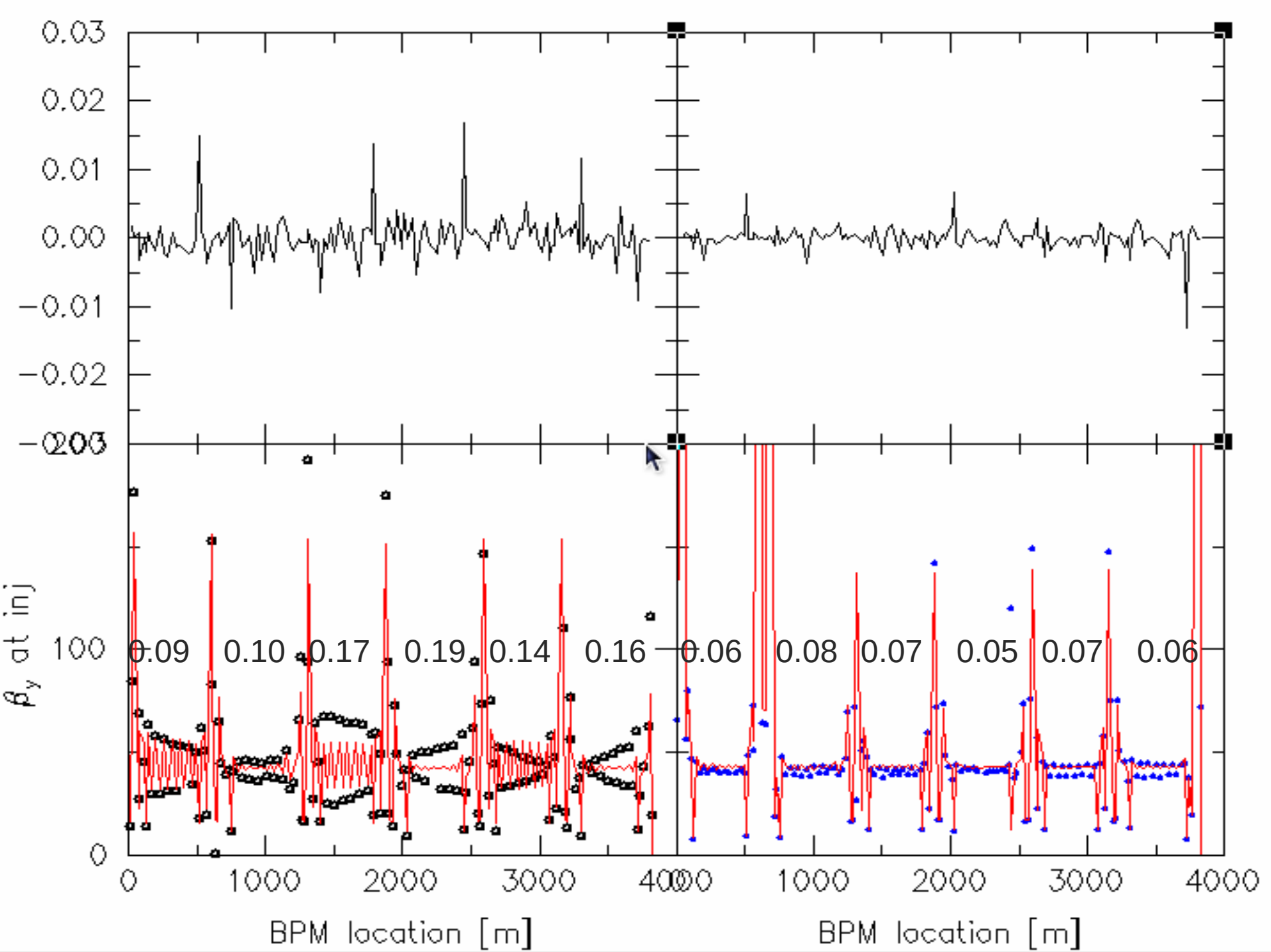
$$(\Delta k_i)_{nquad} = (M)^{-1}_{nbpmxnquad} \left(\frac{\Delta\beta_j}{\beta_j}\right)_{nbpm}$$

- Calculate gradient deviation from the model
- Only work for small perturbation and assume the model is pretty close to reality. However, this may not be the case yet:
  - Qy: 29.656(inj) -> 29.7045(store)


0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
β_x at inj
100
0
0.07
0.09
0.16
0.15
0.14
0.08
0.14
0.12
0.11
0.13
0.14
0.15
0
1000
2000
3000
4000
BPM location [m]
BPM location [m]


0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
β_y at inj
100
0
0.19
0.18
0.24
0.14
0.17
0.10
0.11
0.23
0.13
0.23
0.13
0.15
0
1000
2000
3000
4000
BPM location [m]


0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
100
0
β_x at inj
0.11
0.12
0.11
0.10
0.10
0.11
0.16
0.09
0.11
0.13
0.13
0.16
0
1000
2000
3000
4000
BPM location [m]
BPM location [m]


0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
β_y at inj
100
0
0.09
0.10
0.17
0.19
0.14
0.16
0.06
0.08
0.07
0.05
0.07
0.06
0
1000
2000
3000
4000
BPM location [m]
BPM location [m]

Conclusions

- Good Yellow ORM data for injection and for store were taken and under analysis. The preliminary look at Yellow gradient error analysis suggests the tripplets are the main source of linear optics errors
- A good set of Blue ORM data for store is also in the can for analysis
- The ac dipole data show the betawave in the arcs ranges from 10% to 25%
- Very preliminary analysis was done to calculate the gradient errors from the measured beta wave.

Plans

- Shutdown
  - complete the data analysis or ORM and ac dipole data
    - ORM:
      - Compare corrected yellow injection/store lattices to measured optics
        - Include BPM and corrector gain errors in fits
        - Include coupling
        - Fit more quads in yellow store analysis; understand why full-ring fit becomes singular. Fix yellow tune matching for store ORM.
        - Analyze Blue store data from May 30
        - Analyze May 30 data for both rings with averaged orbits
        - Analyze AGS data with Matlab LOCO
      - Ac dipole: understand the linear optics dependence on the coherent size
  - Comparison of the two methos
  - Design gradient error correction scheme
- With beam
  - Dedicated beam time
    - Gradient error measurement methods
    - test the gradient error correction scheme